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TECHNICAL NOTE

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Inventory Techniques for Sampling Avian Populations

by

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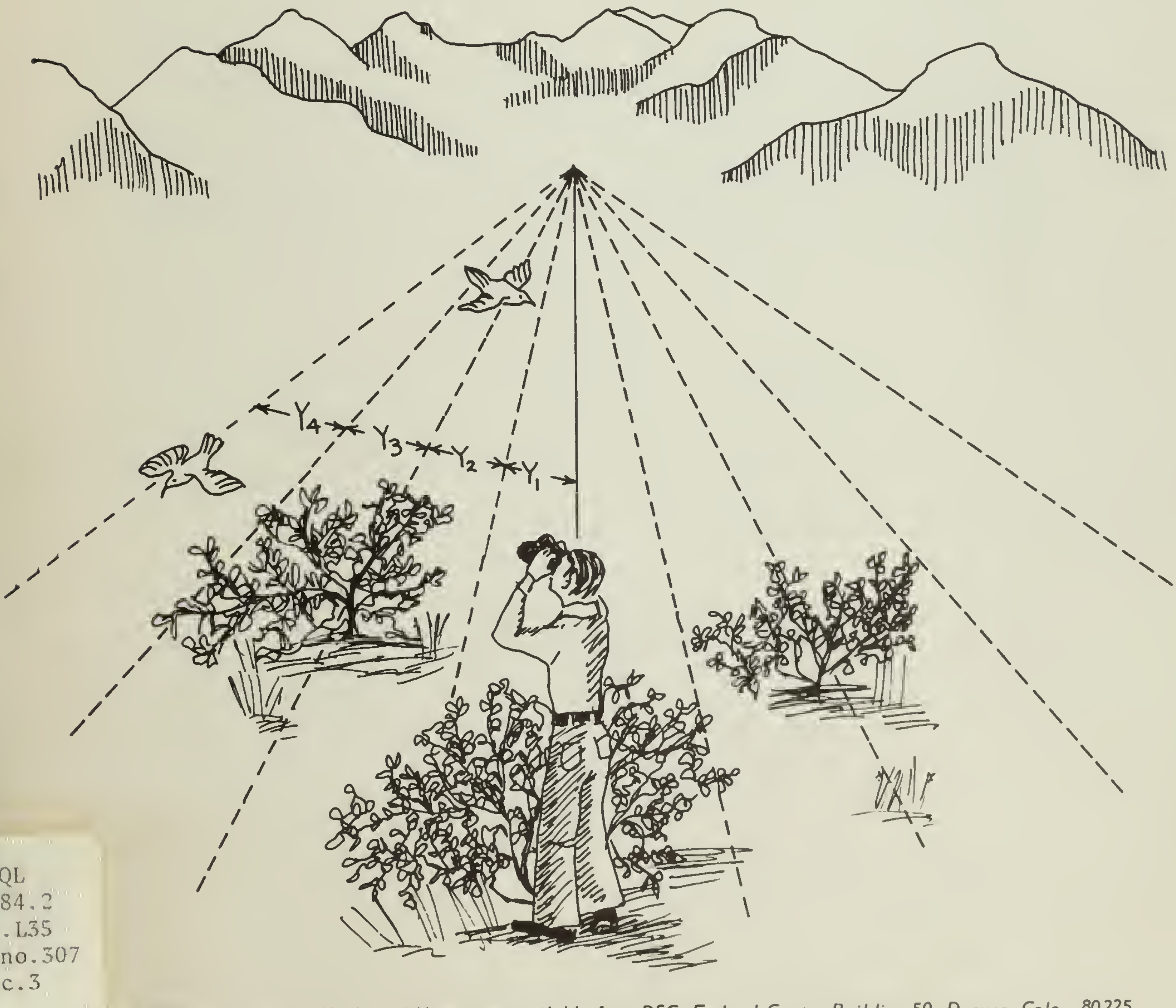

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INVENTORY TECHNIQUES FOR SAMPLING AVIAN POPULATIONS

INTRODUCTION

In order to determine avian species composition and densities in a given area it is necessary to systematically inventory the habitat(s). Three basic types of data can be collected. First, species occurrence information indicates distribution by habitat type. Second, relative density data provides insight into which species are the most common and which are the most rare. Third, absolute density data provides information on how many birds of each individual species utilize a given habitat as well as total numbers of individuals which the habitat is supporting. Of these three inventory types, the latter is the most important because its results indicate the degree to which a given habitat type is being utilized and hence, permits a system of prioritizing habitats on the basis of avian usage. In addition, diversity values such as H´ (see Shannon 1948) may be calculated from density data.

The purpose of this Technical Note is to review the major inventory techniques currently in use for birds. Information regarding how to collect field data, analyze it, and display the results is also included. In addition, where two or more methods are applicable to a particular situation, advantages and disadvantages of each method will be discussed. A list of the most useful censusing techniques and types of birds for which they are appropriate is given in Table 1.

Table 1

APPLICABLE CENSUSING METHODS

Avian Category	Breeding Season	Non-Breeding Season
Terrestrial		
Upland Game Birds		
a) lek species	Transect	Transect
b) non-lek species	Transect, spot-map	Transect Spot-map: Some species
Raptors	Count active eyries	Transect
Nocturnal species	Spot-map with use of taped calls	Transect
Colonial species	Transect (Count nests)	Transect
Passerines (majority of)	Spot-map, transect	Transect
Non-terrestrial		
Pelagic, shorebirds, wading birds	Transect, spot-map	Transect
Waterfowl	Direct count (i.e., photographs), Transect, spot-map	Transect, Direct Count
Marsh species	Spot-map with use of taped calls, transect	Transect

Species Occurrence

Species occurrence merely indicates the presence or absence of a particular species. It does not demonstrate the extent of habitat preferences of species nor the degree of habitat utilization.

Several methods are available to obtain data on occurrence including searching museum records, field notes from university personnel, and articles discerned from library searches of pertinent publications appearing in the literature. To augment these sources, actual field work should be undertaken by systematically traversing the study plot to ensure canvassing all potential sites that may harbor different avian species. Roadside or windshield surveys, though not as accurate as walking through the area, may also be undertaken.

Playing tape recordings of species' calls in dense habitat in order to illicit a response from the bird, works remarkably well for marsh birds such as the secretive rails and for birds which are primarily nocturnal such as owls.

Further, any of the following techniques used in obtaining relative and absolute density information provide data on species occurrence.

Relative Densities

Data obtained for relative density information provide indices of species abundance or occurrence. Such indicies can be based either on number of individuals of species observed per unit of time (i.e., per hour) or number of individuals of a species seen per unit of distance traveled (i.e., per km).

The best approach to collect such data in the field is to systematically traverse transect lines established within the study area while recording each bird seen. Other less efficient methods include direct counts (such as done by photographing waterfowl on wintering ranges), roadside counts (windshield surveys), and random walking through the study area. Data should be depicted separately for each habitat type and at each season of the year. Each inventory should be conducted in as nearly a homogeneous habitat as possible. Heterogeneous habitats may be sampled provided a careful description of the habitat is given including such information as the proportion that each vegetation type contributes to the total flora, plant species composition and densities, and an indication of the observer's path through the area and the vegetation encountered.

The relative density of a particular species is calculated by taking the number of individuals of that species and dividing by the total number of individuals in the sample. This gives an indication of the proporation that each species comprises of the total avifauna.

Absolute Densities

There are numerous methods for determining avian absolute densities, each having advantages and disadvantages. Three of the most frequently employed methods are described below.

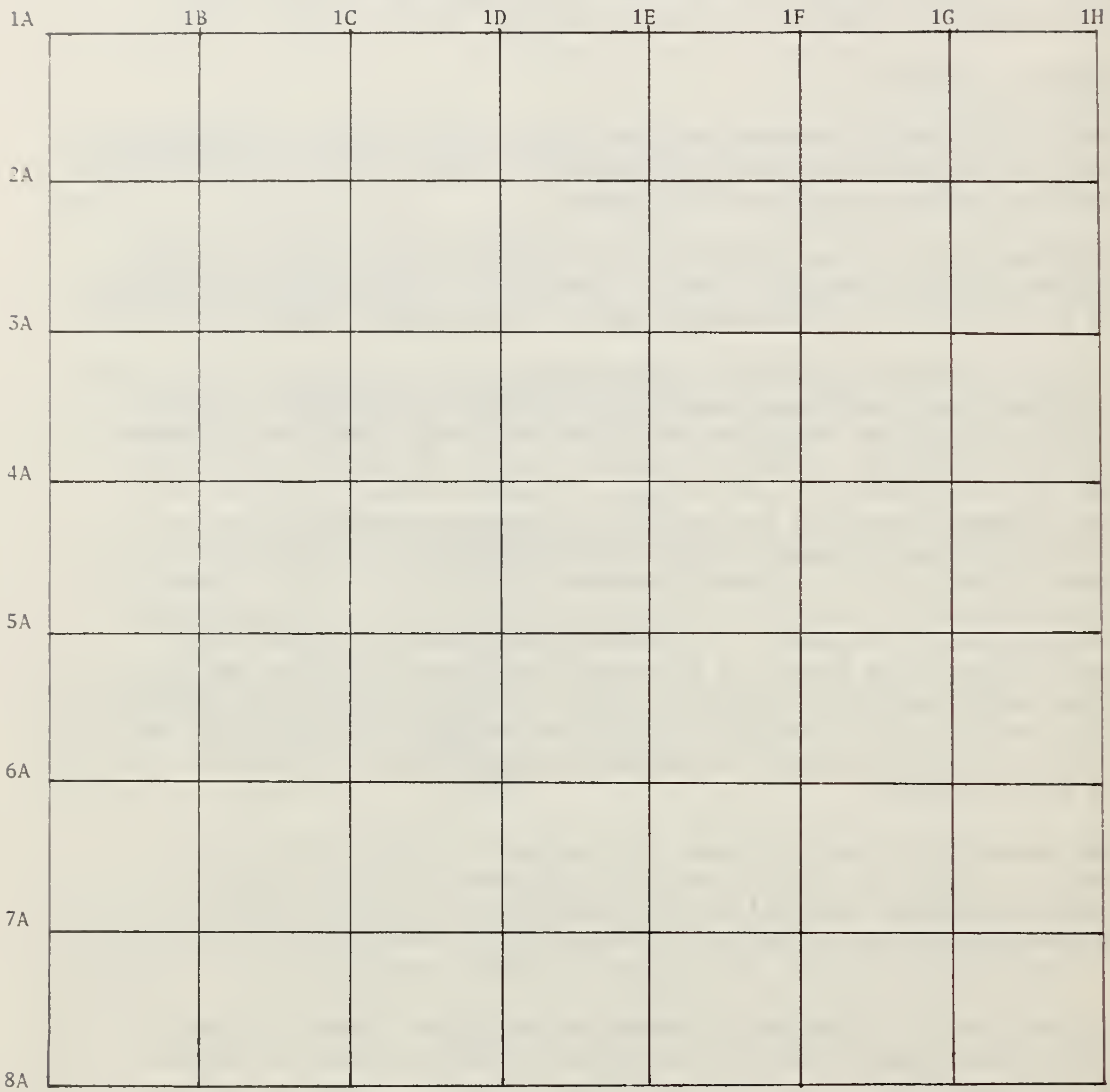
Spot-Mapping. The most widely used censusing technique is the spot-map method (Williams 1936), which with minor modifications is referred to as the international mapping method (see Audubon Field Notes 1970).

The spot-map method involves establishing a grid system consisting of parallel lines forming a square (preferably) or rectangle. Plastic flagging or stakes are placed at given intervals along each transect and are coded with a number corresponding to the transect line and letter corresponding to the distance traveled from the beginning of the transect line (see Figure 1). The distance between flags and distance between transect lines is determined by the density and type of vegetation. In dense forested situations, it is recommended that flags be not more than 25 meters (m) apart and transect lines no more than 50 m apart. In open habitats, transects 100 m apart and flagging 50 m apart may be used. The area encompassed by the grid pattern must be calculated. Grid size will also be determined by type and density of habitat. In closed systems 10-30 hectares (ha) represents a suitable size, whereas in open habitats 40-100 ha would be more suitable.

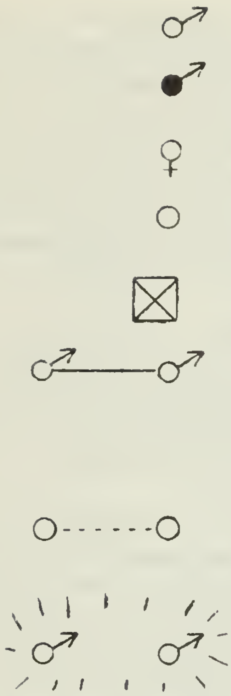
The scale of the map may vary, but generally in dense habitats a scale of 1:1250 to 1:2500, where 1 inch equals 100 feet or 1 inch equals 200 feet, respectively, is suitable. In open habitats a scale ranging from 1:2000 to 1:5000, where 1 inch equals 165 feet or 1 inch equals 415 feet, respectively, is more appropriate.

On each species' spot-map observations should be coded to signify particular critical information. The following system of symbols is recommended:

Figure 1 Sample Spot-map



This particular scheme consists of 8 transect lines 50 m apart with labeled flags or stakes 50 m apart along each transect. This plot encompasses 12.25 ha. For total plot size and individual block dimensions for different habitat types refer to the text.



nonsinging

singing male

female

observation of individual for which the sex could not be determined

nest

two observations of the same individual during the same day. An arrow may be used to indicate the bird's direction of movement

concurrent observations of two different birds of the same species (i.e., two males singing simultaneously)

an aggressive encounter between two birds of a particular species

Symbolism of the international mapping method (Audubon Field Notes 1970 p. 725-726) while different from the above in several aspects, may also be applicable.

Data on simultaneous contacts (denoted by O---O) are particularly important with regard to territorial males as they are helpful in determining boundaries between adjacent territories. Aggressive encounters may also serve much the same purpose. Although actual intraspecific contact between birds is rare, when it does occur it indicates either an individual has trespassed or is, at least, at the territory boundary.

The goal of the spot-map method is to determine the number of territories encompassed by the plot for each species. During the breeding season (and at other times of year for a few species), each male establishes a territory which he actively defends primarily by singing a species-specific song, and to a lesser extent by other displays. Most species are intraspecifically territorial, defending the territory against only members of their own species. Breeding bird density for a species is derived by multiplying the number of territories of that species by 2. To achieve this goal, the observer walks along each transect, recording the following information for each bird observed: bird species, sex (if possible), age (fledgling vs. adult), singing male, nonsinging male, nest, and location of bird. This information is indicated on a pre-drawn map of the grid pattern for each species. After a number of observations are collected, territorial boundaries for each breeding pair are delimited. The number of territories for a particular species multiplied by 2 represents that species breeding bird density. A sample spot-map is represented in Figure 2 which depicts territorial boundaries for Yellow-rumped Warblers (Dendroica coronata) in a mixed-coniferous forest from data collected for 9 censuses. Since there were three territories encompassed by the 12.25 ha grid plot, the breeding bird density was 19.59/40 ha.

Censusing should be conducted ½ hour after sunrise and continue for no more than 3 hours, as this period of time corresponds to the highest avian activity level. The pattern of walking along the transects should be varied to ensure coverage of each part of the plot at different times of the early morning, thus reducing potential bias in the data.

It is recommended that 3 censuses per month, conducted closely together (but on different days) should be done for 3 consecutive months during the breeding season. Selection of months will be dependent upon area being sampled with respect to avian initiation and completion of the breeding season. For northern habitats sampling should probably begin mid-May or early June and continue through August. In dense habitats more than 9 censuses may be necessary.

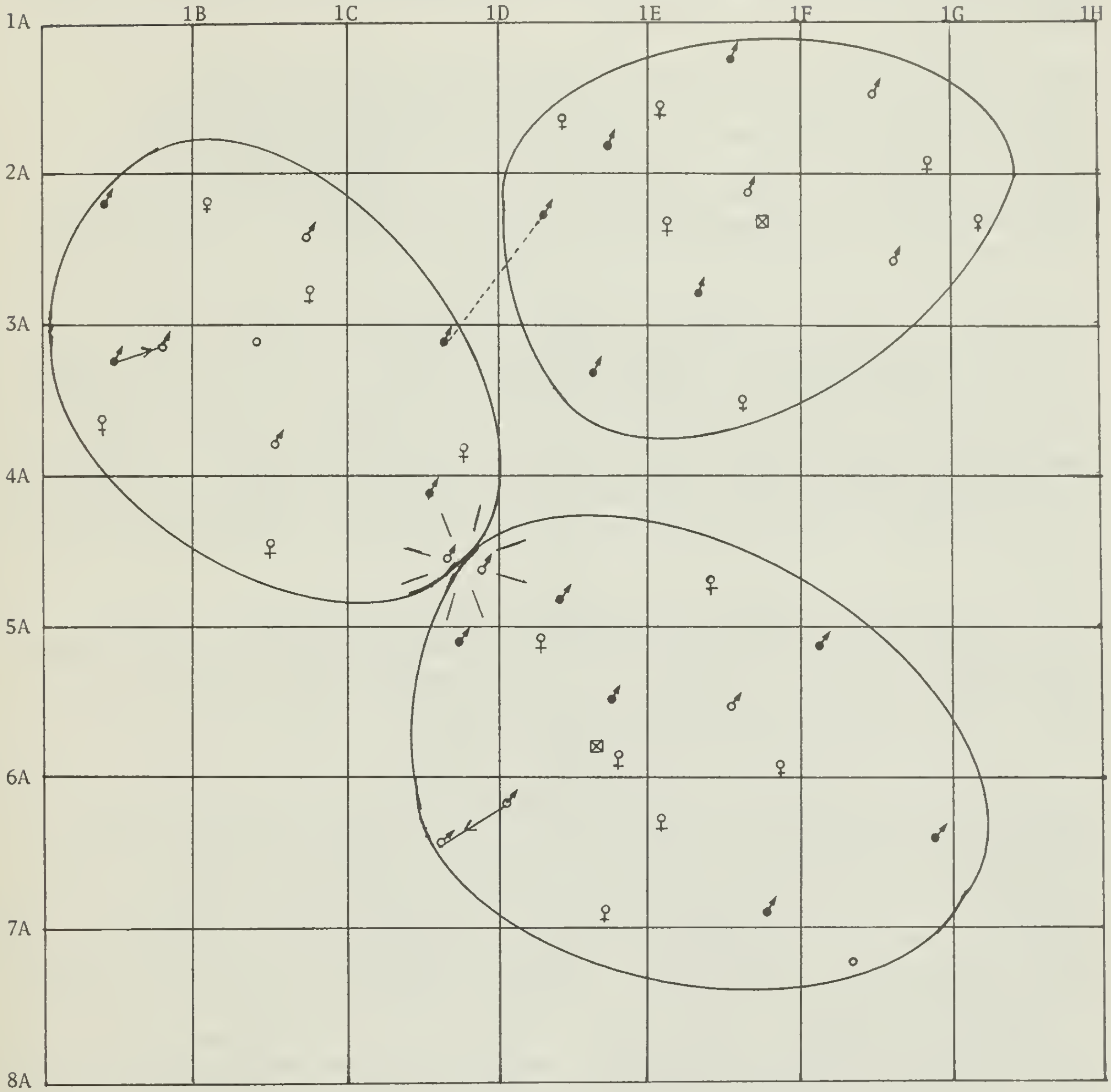
In desert habitats 9 censuses should suffice and should be conducted during March, April, and May. The sampling dates may be modified to reflect prevailing climatic conditions which may either inhibit or accelerate initiation of breeding.

Data for the entire breeding season can be averaged unless a given species has a decided peak in breeding activity during one month. If this occurs, the peak density value for that species should be used.

Grid patterns should be established in homogeneous habitats, otherwise a problem with edge effect may be encountered. In addition, it is difficult to determine habitat usage by either individual species or the local avifauna in heterogeneous habitats.

Partial territories - the boundaries of which do not lie entirely within the plot - are handled by estimating the portion of the total territory which is within the plot borders. It is then treated as a fraction of a territory. For example, if .5 (one half) of the territory is within the plot, and this is multiplied by 2 (since each territory contains a breeding pair), the value of 1.0 will be incorporated into the density figure for that species.

Figure 2 Spot-map for the Yellow-rumped Warbler (Dendroica coronata) in a mixed-coniferous forest.[1]



[1]Blocks are 50 m by 50 m producing a grid plot of 12.25 ha. Symbolism follows that specified in the text. Total breeding bird density is: 3 territories X 2 = 6 breeding Yellow-rumped Warblers per 12.25 ha or a density of 19.59/40 ha (or 19.59/100 ac).

Generally, density values are converted into #/40 ha as this corresponds to #/100 acres (ac), a frequently used data base for avian studies appearing in the literature.

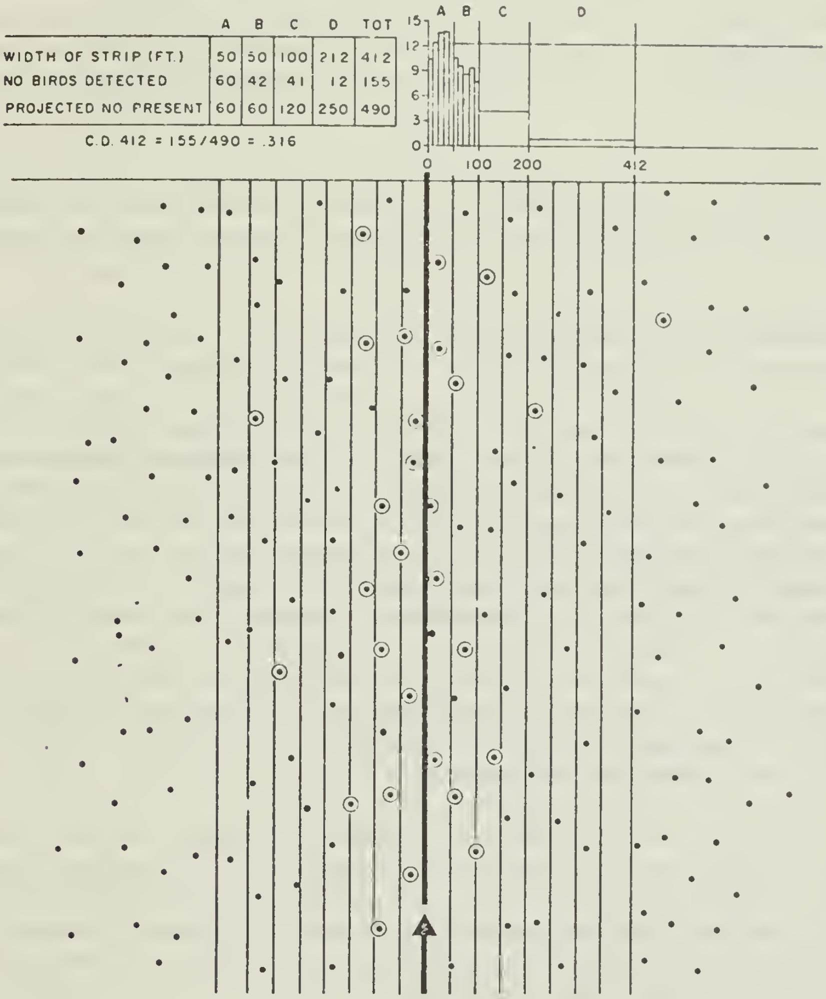
Spot mapping has most successfully been used for non-colonial terrestrial bird species which have a type A territory (this is a territory within which mating, nesting, and foraging occur). In addition, nocturnal birds such as owls can be sampled with the spot-map technique by playing taped recordings of their calls during the night and illiciting responses which are then mapped. Tape recordings are also used to census the secretive marsh birds such as the rails.

Spot-mapping may also be used to sample polygynous species such as the Red-winged Blackbird (Agelaius phoeniceus) and Yellow-headed Blackbird (Xanthocephalus xanthocephalus). To be accurate, each female or active nest within a territory must be included on the map. Breeding bird density is then determined by counting the number of breeding females and males inhabiting the given area and dividing by the number of hectares sampled. The minimum, maximum and mean number of nests found in territories of each species should be included to indicate habitat quality.

Since for the vast majority of species the spot-map method is only applicable during the breeding season, another method must be employed during other times of the year. In recent years Emlen's (1971) variable strip transect method has received wide usage and may, in fact, also be used during the breeding season.

Variable Strip Transect. For the variable strip transect method, a transect of given length is established. The observer walking along the transect, records the following information for each bird observed: the lateral distance of the bird from the transect line, species, whether the bird was singing if it was a territorial male, sex (if possible), and age (fledgling vs. adult). A coefficient of detectability (CD) is derived for each species. The CD represents the proportion of the population which an observer can detect while running the transect. It varies with species and habitat. Densities and CD values are determined by counting the number of birds found in strips on both sides of the transect from the base to the point of inflection on the distribution curve of the results. Since detectability varies with distance from the transect line, the area in the strips when multiplied by the appropriate value will yield the expected number to be found within 125.6 m on both sides of the transect line. For example, if the maximum number of birds occurred in the 15.2 m strips on each side of the transect line, this number when multiplied by 8.24 will give the total number expected. An example of data derived from a hypothetical transect census and subsequent density results is given in Figure 3 (from J.T. Emlen, 1971), where the density of the species in this particular case is 490/200 acres (or 245/100 acres). A more detailed description of this technique is provided by Emlen (1971).

Figure 3 - An example of the variable-strip transect method - (from J.T. Emlen 1971, p. 328-329) Reproduced with permission of author.



	A	B	C	D	TOT
WIDTH OF STRIP (FT.)	50	50	100	212	412
NO BIRDS DETECTED	60	42	41	12	155
PROJECTED NO PRESENT	60	60	120	250	490

C.D. 412 = 155/490 = .316

Schematic model of a stand of vegetation with randomly scattered birds (dots) bisected by a transect route (median line). Dots representing birds that are detected by eye or ear are encircled in the model. Lines parallel with the transect route at 50-foot intervals define strips of coverage. Hypothetical counts of birds on a 2-mile traverse of the transect are tabulated and graphed for each strip or substrip at the top right of the figure. A horizontal line at the top of the graph extrapolates the level of the mean of the first five 10-foot substrips (12 birds) horizontally to a boundary line at 412 feet. Assuming complete coverage in these basal substrips, and random distribution of birds, the area below this line represents the population of a 2-mile segment of the 824-foot band (100 acres). This area (total projected population of 490 birds) divided into the area of the columns (155 birds detected) gives the percent of birds within the band that are detected, i.e. the coefficient of detectability for the birds of this stand (155/490=0.316 in this hypothetical sample). Hypothetical counts of birds on a 2-mile traverse of the transect are tabulated and graphed for each strip or substrip at the top of the figure.

The transect line should be established in homogeneous habitat - well within the boundaries of such a habitat in order to minimize edge effects. If the transect is 4 km long and 125 meters on each side of the center line are sampled, the results will represent number of birds per 100 ha. If a 1 mile transect is run, censusing 412' (126 m) on either side, the results are in terms of #/100 acres. Conversion from acres to hectares or vice versa is quite simple (2.47 ac = 1 ha).

The Emlen variable strip transect method can be used at any time of the year. As in the spot-map method, the most appropriate time to conduct the census is ½ hour after sunrise and continuing for no more than 3 to 3.5 hours.

The observer should travel along the transect at a speed of approximately 1-2 mph in open country and ½-1½ mph in more forested situations.

Each transect should be sampled a minimum of 3 times (Emlen 1971), preferably on 3 consecutive days, weather permitting. However, it is recommended that in moderately dense or very dense habitats, a census of 6 or more days be done as it is more accurate especially with regard to species in low densities some of which may be missed altogether if only 3 censuses are conducted. An average of the results for each species can then be determined. During the breeding season it is advisable to sample a minimum of 3 times per month (or more in denser vegetation), with the days as close together as possible. Results can be averaged for the entire breeding season unless a particular species has a pronounced density peak for a given month. If so, this peak density value should be used.

The variable strip transect method is very satisfactory for most terrestrial species such as doves, hummingbirds, woodpeckers, and passerines. However, according to Emlen (1971) it is not useful for "wide-ranging water birds, shorebirds, hawks, nocturnal birds, for treetop birds in tall dense forests, and for swifts and swallows that cruise about above the vegetation."

Both the spot-map and variable strip censusing techniques have advantages and disadvantages. With the variable strip method, one person can sample large areas easily. According to Emlen (1971) only 3 replications are needed, whereas 10 are recommended for the spot-map method. Variations in detectability among species and between sexes are taken into account to a certain extent. Once CD values have been established, a similar habitat can be quickly censused. Also, all birds, both breeding and nonbreeding, are censused (including fledglings).

However, there are problems with the variable strip method. Males involved in territorial advertisement become less conspicuous as the breeding season progresses. Males of some species become less vocal once the females begin incubating or the young hatch. It is difficult to distinguish such a nonsinging territorial male from any other male who may wander through the area. Conspicuousness of females also declines beginning with incubation. Shyness of some species makes it extremely difficult to detect them even at close range. These factors may make it difficult to arrive at a reliable CD and may substantially affect the overall population estimate. The calculation of the densities is another problem. The CD depends upon the distance of each bird from the transect line and the absolute detectability of the bird. It is assumed that all birds were detected within the strips on either side of the transect line bounded by the point of inflection in the distribution curve. In an area with fairly dense vegetation, this assumption may not be valid. If not, the total density value will be less than the actual number. This may account for the lower densities estimated using the variable strip transect count versus the spot-map method found in a recent study (Franzreb 1976). Thus, the data from the former should be multiplied by a basal detectability value (see Emlen 1971). However, this conversion factor will be only as accurate as the results derived from another sampling method. Hence, applying a basal detectability adjustment factor to the data, while perhaps desirable from a theoretical standpoint, is impractical and therefore, need not be attempted.

Emlen (1971) noted several other problems with the variable strip transect method. Identification skill of the observer, observation conditions such as weather, and misjudgment of distance are further sources of error. Also, with only three trips through the study area, a low density species may be missed.

Emlen (1971) recommended comparing data for singing males X 2 with results obtained from all other observations and adopting the higher value. I suggest that one rely on the highest number of observations in one of three categories (singing male data X 2, all other observations, or total observations). In some cases there may be a high number of "all observations other than singing male: but after singing male data are multiplied by 2, the latter may be greater. However, if the singing male data are instead added to all other observations, the resultant value may be the highest. Also, multiplying the territorial singing male data by 2 may underestimate the population size since the nonsinging, territorial males are not included. Furthermore, if all observations are considered, including singing and nonsinging territorial males, the population may still be underestimated since females may be under-represented because of nesting activities.

In addition, if avian densities vary annually, during years of high densities, territories may be compressed and territorial males more vocal, thus increasing their detectability. Hence, a new CD would have to be calculated. Furthermore, CD values may vary seasonally. Also, in order to derive densities CD values are not essential. They are designed to quickly enable a person to census a similar habitat without going through most of the other necessary computations. From a practical point of view and as a result of the aforementioned problems associated with them, CD's are of limited value.

As for the spot-map method, one advantage is that if territorial males are accurately counted, the number of breeding birds can be reasonably predicted, but this is not easily done. On the other hand, in interpreting spot-maps it is useful to know territory size. However, for many birds territory size is not well-known and varies with many circumstances such as habitat, breeding bird density, and individual differences in aggressiveness (Schoener 1968). This is not usually a problem for species with low densities since territories may be more widely spaced. With high density species it is difficult to delimit one territory from all adjacent ones. If territory size is underestimated population density will be too high. This may account, in part, for the discrepancy in density estimates for some species when comparing the variable strip transect to spot-map results (Franzreb 1976).

Kendeigh (1944) criticized the use of singing males to indicate number of breeding pairs since a considerable proportion of them may be unmated. For example, he found that 9% of the singing male House Wrens were unpaired. Variation in degree and strength of vocalizations occurs among species. The spot-map method does not distinguish between paired and unpaired birds and does not consider variation in adults or territories during the raising of second broods (Kendeigh 1944).

Mapping territories is time consuming and requires at least three readings through the study area per month; Kendeigh (1944) indicated that five per breeding season were necessary. In addition, certain members of the population are not counted, such as the nonbreeding adults and the fledglings. Toward the end of the breeding season territories begin to break down and accuracy of spot-mapping declines rapidly. One big drawback to spot mapping is that it is applicable only when birds are reproducing. For most species, this is the only time that singing occurs and territories are maintained.

Strip/Belt Transect. A third method of deriving absolute densities involves sampling a strip of known length and area (Merikallio 1946, 1958) or sampling strips of appropriate widths determined by each species characteristic detection distances (Kendeigh 1956). The largest tally for a species found during a series of replications can be adopted to reduce degree of incompleteness of any single count. In this method (referred to as a strip or belt transect), a transect of a set width and length is established. All birds observed within this belt are counted. The species density value is calculated from number of birds observed per unit area encompassed by the strip boundaries.

The number of transects necessary, their spacing, and seasonal applicability follow the recommendations given for the Emlen variable strip method.

Strip or belt transects are not the most commonly used methods in avian inventory work as spot-mapping and Emlen's variable strip transect method in the majority of situations are more accurate, efficient, and appropriate. However, in narrow riparian habitats this method is quite useful since a belt transect can easily be established and censused along vegetation adjacent to a stream or pond.

Nest Counts. During the breeding season, nest counting can be reliable for colonial nesting species providing the majority of nests are located. Each nest represents a breeding pair. Such species include most swallows and many pelagic birds which form loose colonies at breeding time.

Many shorebirds can be censused using a count of their nests provided censusing is done at the appropriate time during the nesting cycle. Some of these species such as killdeer, avocets, stilts, sandpipers, etc., generally do not construct an elaborate nest and their young leave the nest site soon after hatching. Hence, censusing must be done during the incubation stage.

Location of raptor nests (active eyries) is also a good method for determining densities of hawks and eagles. Unfortunately it is a time consuming approach.

In the above situations nest counts usually provide only relative density information. Unless the amount of habitat utilized by the birds can be determined, absolute densities can not be calculated. If the amount of suitable habitat is known and if the number of birds utilizing the suitable habitat can be assessed, then absolute densities can be derived.

METHODS

Selection of Censusing Technique

The censusing method selected should depend upon the circumstances. In situations where dense vegetation may hamper detectability, resulting in underestimation of population size, the spot-map method may be more accurate. Narrow riparian vegetation can conveniently be censused using a strip of a given width. Counts of nests may be most appropriate for certain species. Availability of personnel may be a consideration because the variable strip transect method requires less time and fewer observers to census a given amount of habitat.

Basically, the technique selected will be dependent upon time of year, type of habitat, individual characteristics of the species being censused, and personnel availability.

Regardless of censusing method selected, the habitat being inventoried should be thoroughly described. The location description should include the state, county, topographic map name, township, range, and section number(s). A brief description of the vegetation, substrate, aspect, slope, ground cover, as well as pertinent information on influences such as grazing, human activity, or other forms of modification can be sufficient. However, more elaborate bird census methods such as spot-mapping and transect censusing require a vegetational analysis of the study plot, employing a technique such as the plotless-pointer quarter method (see Cottam and Curtis 1956) in order to adequately describe the site. This analysis may include such information as tree species density, tree species composition, tree species frequency, and importance value of each individual tree species to the flora (importance value equals the sum of relative frequency, relative density, and relative dominance, see Cottam and Curtis 1956). The understory vegetation should also be described.

Censusing should be conducted beginning one-half hour after sunrise and continuing for up to 3 hours since this time period corresponds to highest avian activity. Each census should be conducted under similar weather conditions. The sky should be clear with little, if any, wind as these provide the best sampling conditions. Wind is particularly important as even a gentle breeze (a wind velocity equivalent to 3 on the Beaufort scale), may appreciably reduce activity of the smaller passerines, thereby affecting censusing data.

Ideally, every study plot should be surveyed during each season of the year. With limited time and personnel constraints, it may not be possible to sample during each season. If such limitations exist, spring/summer should be high priorities since it is during this period of time that nesting occurs.

SPECIAL CONSIDERATIONS

Comparison of Censusing Results

In order to determine which habitats support the most birds it is best to compare results obtained in the different habitats from the same censusing method. As previously discussed, generally spot-mapping yields higher results than does the variable strip method. Hence, to compare habitats which were censused with dissimilar techniques would be inappropriate.

Comparative censuses should be done at approximately the same time, in the same general locality, and ideally by the same observer as there is some interobserver variability.

Care should be exercised in comparing results from habitats sampled in different years as climatological factors can strongly influence density results. This is also true in examining results from the same habitat censused during different years. For example, there can be considerable variability in individual species densities as well as in total avifaunal density for the same habitat in censuses conducted consecutive years. This points out the necessity of having several years of data for any particular habitat.

Flocking

Flocking behavior either in mixed species or single species flocks is a common behaviorial pattern in many birds especially during the non-breeding season. Several approaches are available to census such flocks.

The most practical method is to establish a strip or belt transect and census all birds, flocking and non-flocking, within the transect boundaries. When a flock is encountered the number of birds belonging to each species must be determined so that a density figure for each species can be derived.

Coveys of quail can be censused similarly. In addtion, many such quail flocks maintain a restricted home range or territory (although it is undefended and hence, does not qualify as a true territory). Such coveys can be spot-mapped during the winter.

Diversity

Diversity refers to the distribution of observations among the different categories. In a situation where there is a high diversity, the observations are evenly distributed among the categories (in this case among the species). A habitat possessing a low species diversity has most of the observations occurring in one or a few categories (species).

Quantitatively, diversity (H') is measured by Shannon's formula (Shannon 1948)

$$H' = -\sum_{i=1}^{k} p_i \log p_i \quad \text{where}$$

p_i is the proportion of observations occurring in the i^{th} species.

Since the size of H' is affected by the distribution of the data as well as the number of categories, it is sometimes preferable to also calculate the ratio (J') of the observed diversity to the maximum possible diversity (H'_{max}). $J' = H'/H'_{max}$ where $H'_{max} = \log K$ whereby K is the number of categories. J' is therefore an indication of evenness (Pielou 1966).

These values indicate if the habitat is supporting a diverse or meager fauna. It also shows distribution of the individuals in the various species. Generally speaking, habitat stability and complexity increase with increasing diversity.

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